Probabilistic Analysis and Non-Linear Semi-Active Base Isolation Spectra for Aseismic Design

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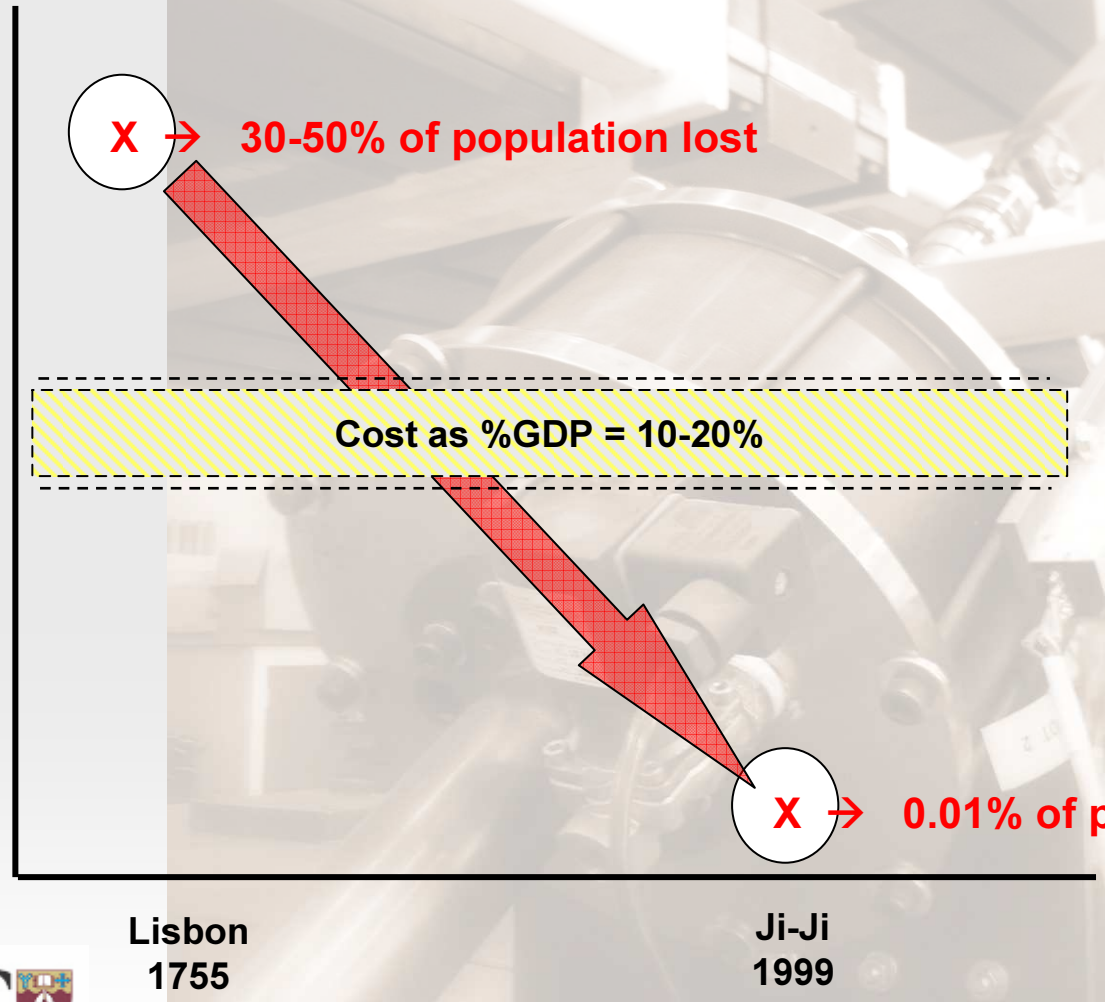
A Simple Story



- For relatively large design events
- Lives lost has gone down to nearly zero
- Cost and economic damage has remained constant

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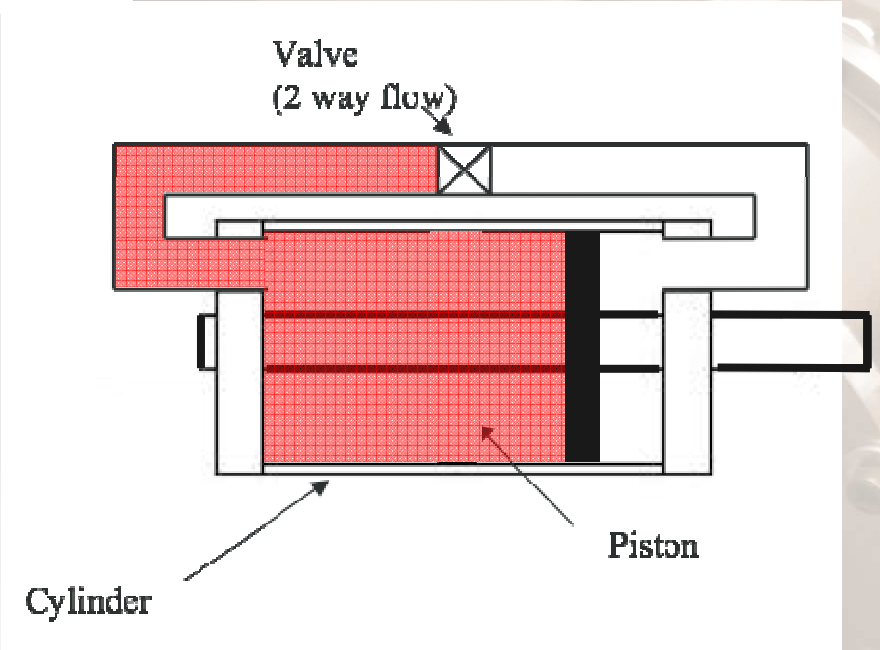
Base Isolation – Newer and Older

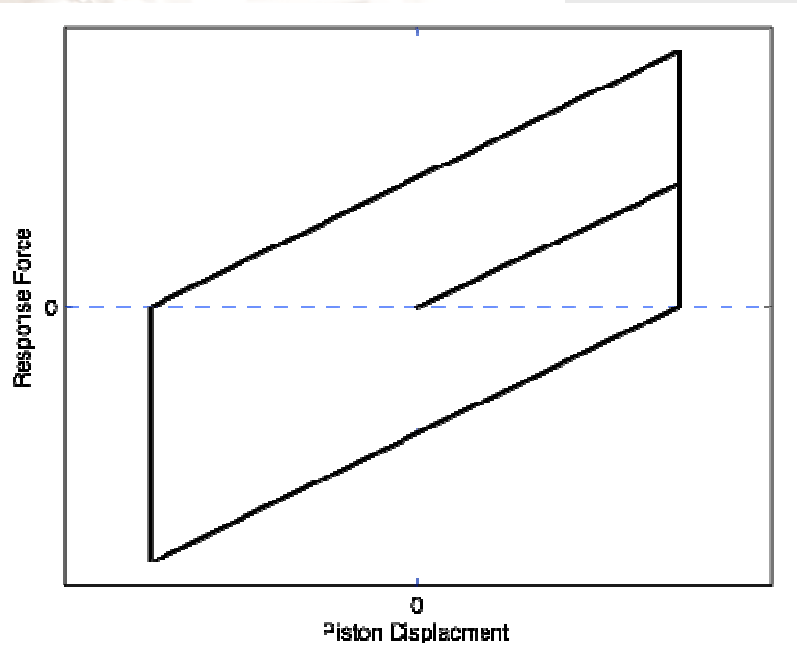
Te Papa -base isolated

Lead rubber bearings

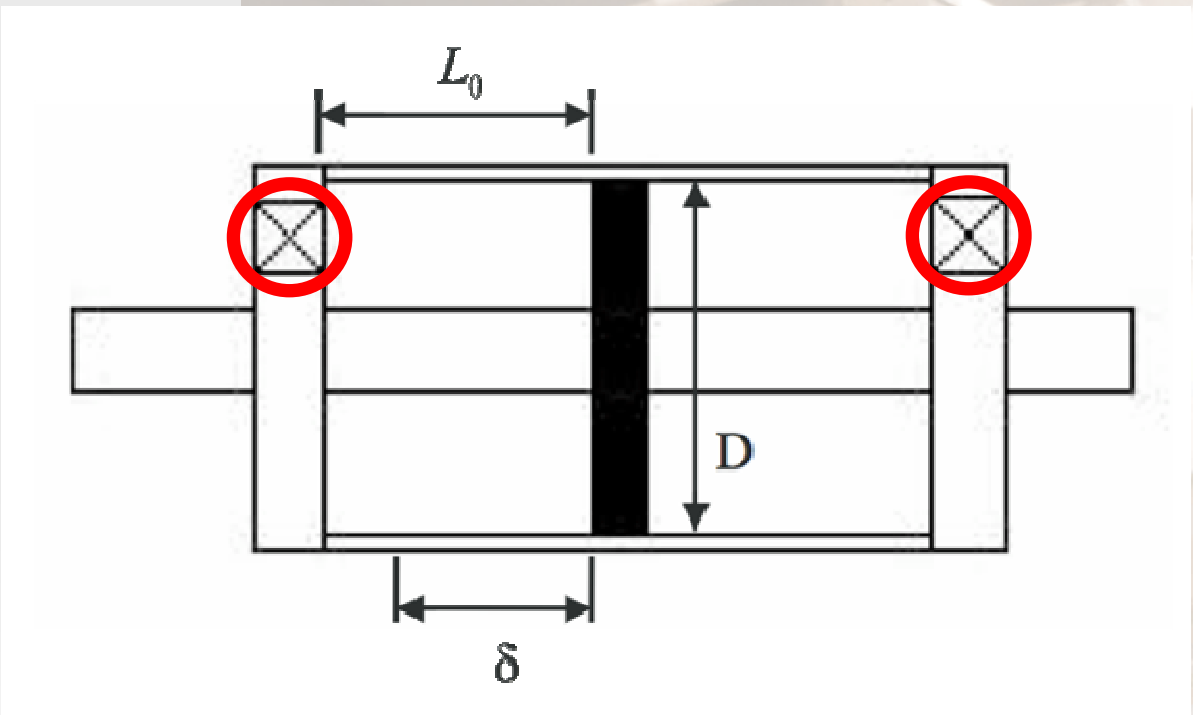
What is a Resetable Device?

Spring with a controllable reset (unstressed) length



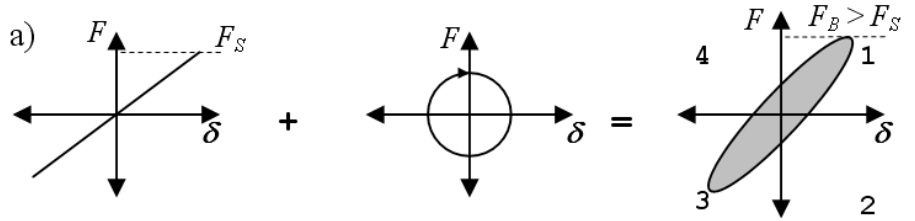


1 Small Change → Big Implications



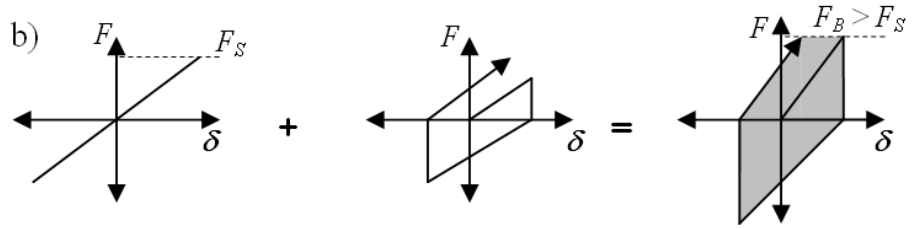
Customised Hysteresis

Resist all velocity



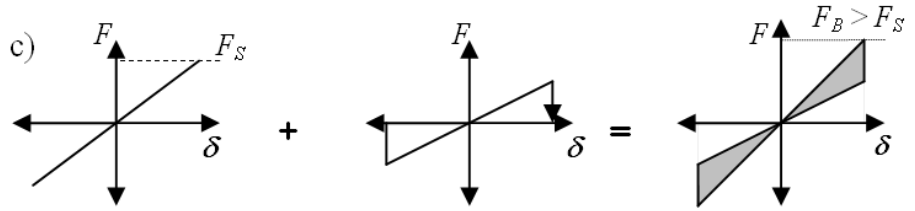
Viscous Damper

Resist all motion



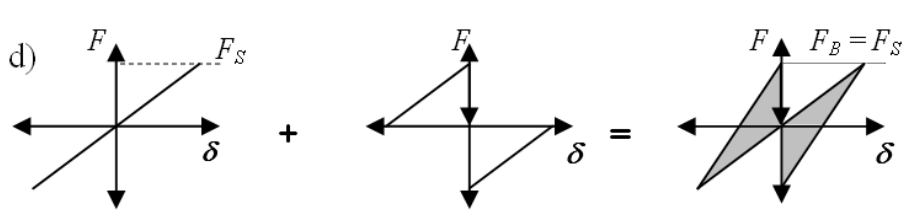
1-4 Resetable

Resist motion away from 0



1-3 Resetable

Resist motion toward 0



2-4 Resetable

Which is best for base isolation – if any?

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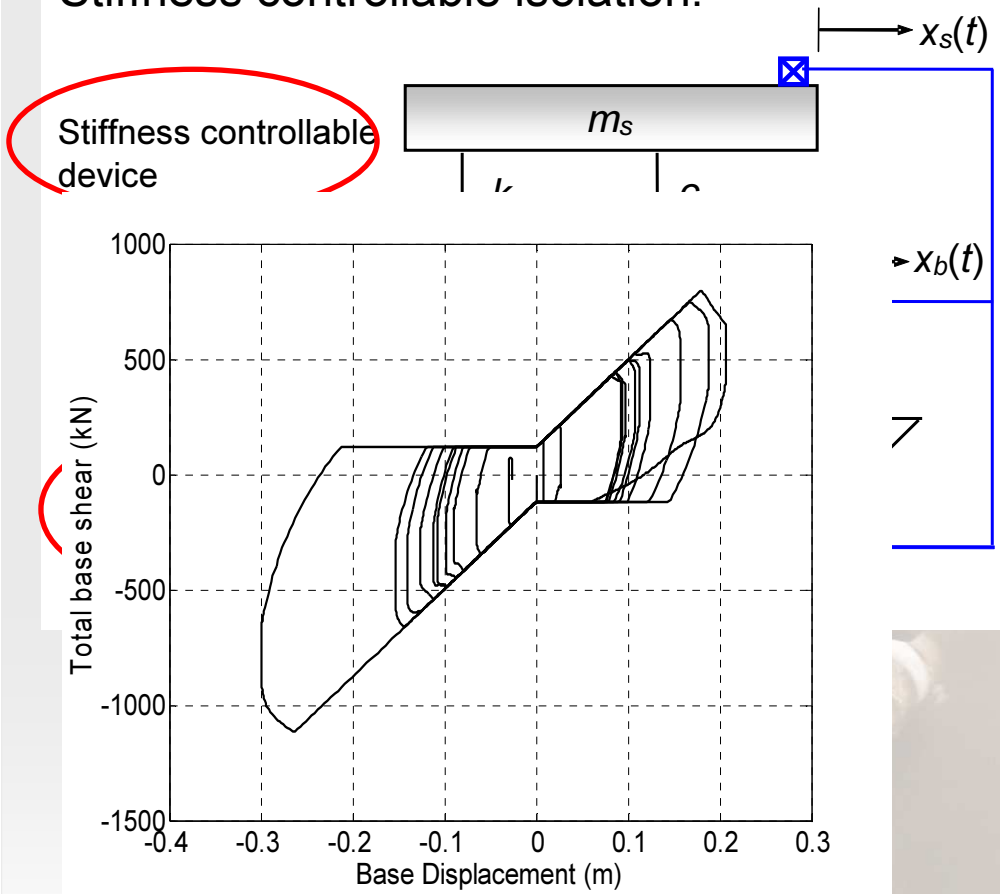
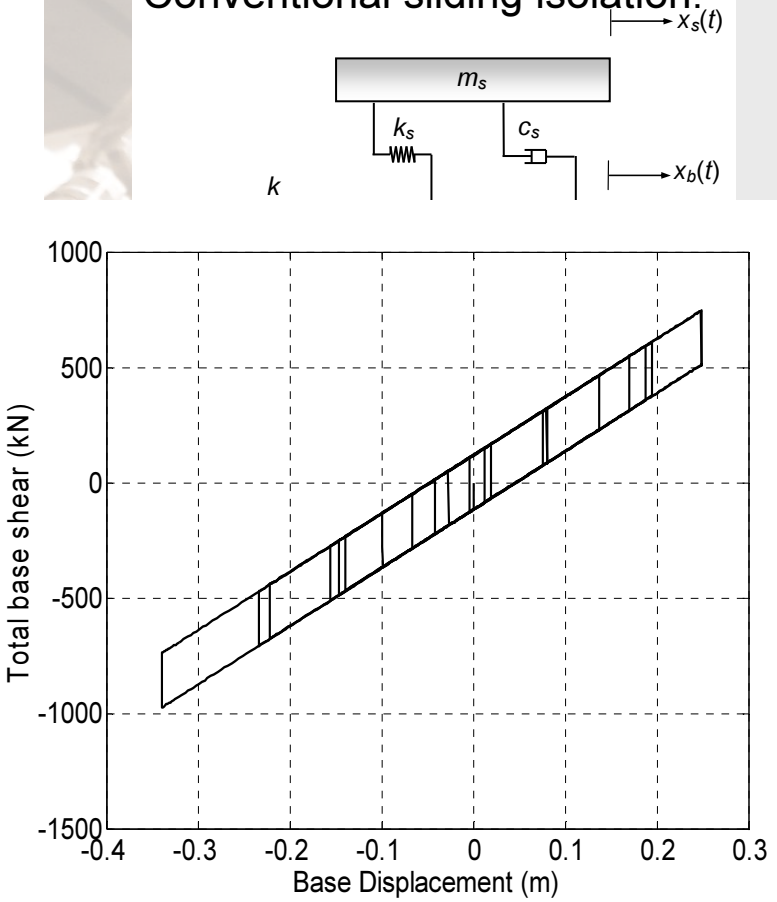
Optimal Active Base Isolation

Stiffness controllable isolation:

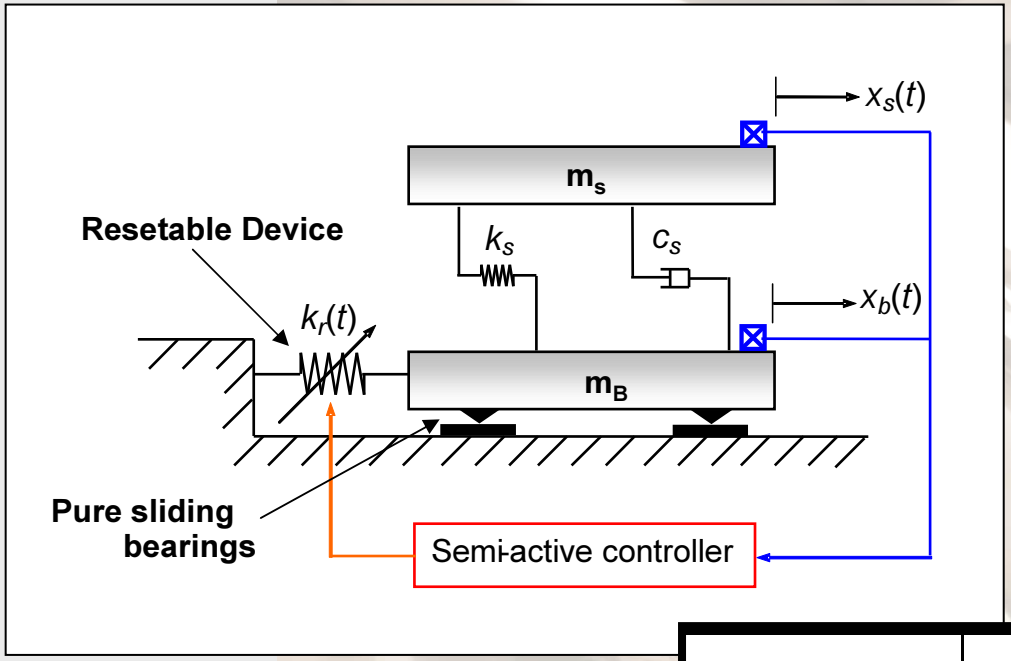


Conventional sliding isolation:



- **Active, optimal base isolation looks just like 1-3 semi-active resetable device control!**

The System



System	Item	Value
Super-structure	Structural mass (m_s)	300 ton
	Structural stiffness (k_s)	3.289×10^4 kN/m
	Damping coefficient (c_s)	3.141×10^2 kN-sec/m
	Frequency (f_s)	1.67 Hz (fixed-base)
	Damping ratio (ζ_s)	5 % (fixed-base)
Isolation system	Mass of base mat (m_b)	100 ton
	Friction coefficient (μ)	0.03
	Range of controllable stiffness (k_r)	0.0 - 3.79×10^3 kN/m

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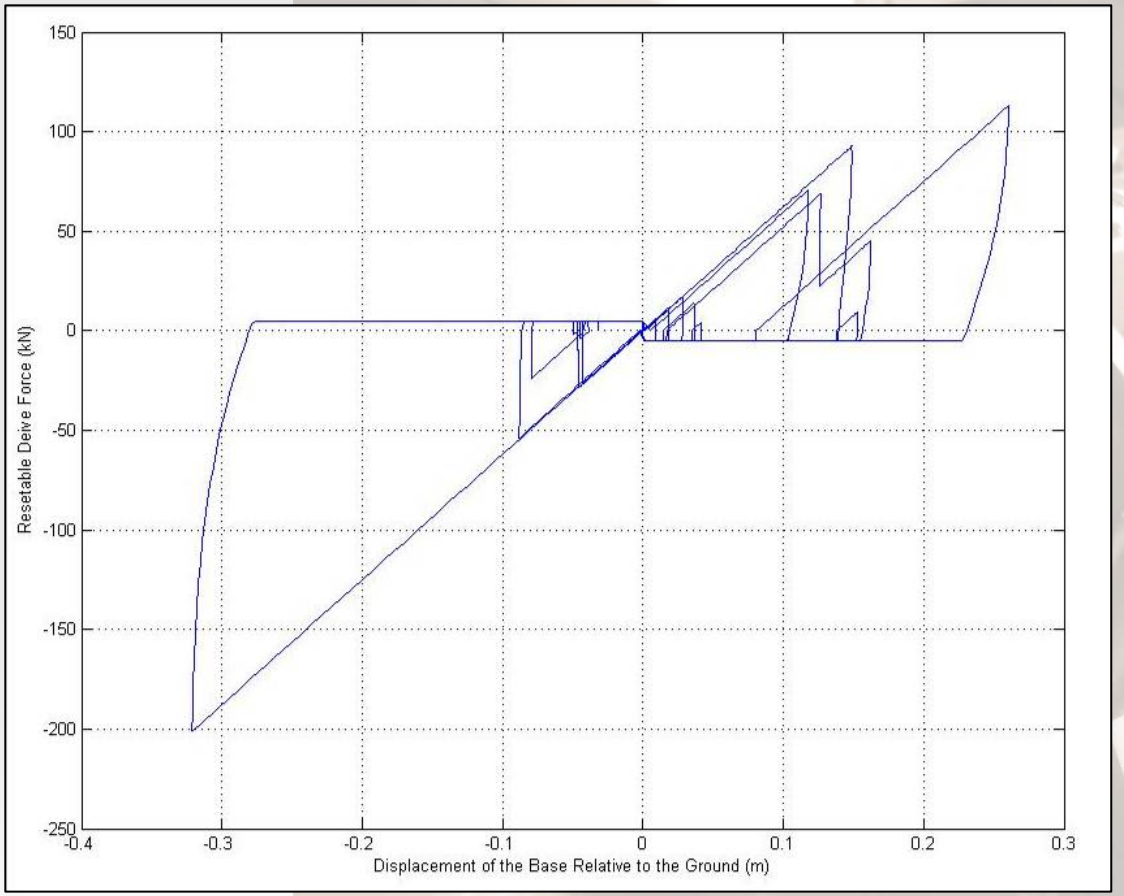
The Device



- Resist motion away from equilibrium (zero)
- Free sliding back to equilibrium (zero)
- Light sliding friction to keep velocity down
- Should be “common sense”
- Easily done with these novel resetable devices

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The Analysis

- Three (3) suites of 20 earthquake records from the SAC project
- Passive isolation benchmark tuned to:
  - O.1 Hz (T = 10 sec)
  - 0.2 Hz (T = 5 sec)
- Resetable device stiffness set to:
  - Same stiffness as T = 5 sec passive solution
  - 1.5x stiffness of T = 5 sec passive solution – stiffer to minimise displacement and create a “conservative” less isolated comparison.
  - Stiffer solution also minimises base motion
- Median, IQR and 90% CI reported over each suite for displacement and acceleration performance

The Results: Structure

- **Peak Base and Structural Accelerations**
  - **5x lower than passive system for all suites → better isolation & control**
  - **As compared to more optimally tuned T = 10 sec passive solution**
- **Peak Structural Displacement**
  - **4x lower than passive systems for all suites → better isolation**
  - **As compared to more optimally tuned T = 10 sec passive solution**
- **Peak Base Displacement**
  - **1.5-2x higher than passive for all suites**
  - **Less than 400mm standards for low and medium suites**
- **Only modest degradation across resetable tuning, even if it is less than optimal (e.g. stiffer device)**

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The Results: Base Motion

- **Final Base Displacement**
  - **Typically less than 50mm, but higher than passive – need more centering stiffness**

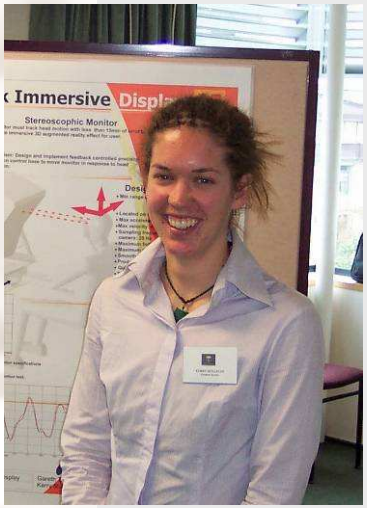
- **More base motion, but overall better isolation**

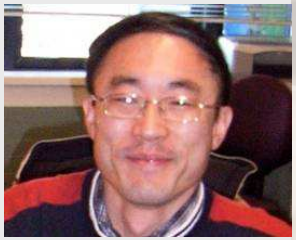
- **Could easily tune device stiffness (higher) and friction properties to get a more optimal solution for all performance metrics**

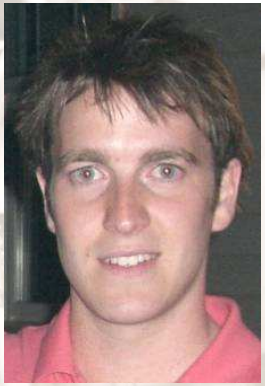
Conclusions

- Novel resetable devices can enable significant new applications
  - Open several new design avenues not previously available
  - Base isolation is one new application where the semi-active capability allows a passive system to adapt to ground motion frequency content
- Large reductions in displacement and acceleration metrics
- Straightforward tuning and design
  - Suites of records show robustness to all types, frequency content, and magnitudes of events
  - Robust to “poor tuning” with stiffer device choice with no loss of performance over optimal results
  - Outperforms a better (longer period) passive solution
- Other control laws might also provide benefits with equally acceptable performance

Thanks to....







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Questions?